Tide Mark or Tidal Datum: The Need for an Interdisciplinary Approach to Tidal Boundary Delimitation

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With increasing competition for coastal resources and a concomitant rise in property values, the precise delimitation of property rights and boundaries is emerging as a major public issue in Canada's coastal zones. Of particular concern, at least in the Maritime Provinces, is the ambiguity and confusion surrounding the delimitation of tidal boundaries. Recent court cases in New Brunswick and Prince Edward Island demonstrate the need to clarify legal and scientific terminology and the technical procedures employed in surveying these boundaries.

Des litiges relatifs au droit de possession des ressources découvertes au large des côtes, alliés à l'accroissement de la valeur des biens-fonds, découlent des débats d'envergure au Canada sur la détermination exacte des droits de possession et des limites en ce qui a trait aux zones côtières du pays. On se préoccupe surtout, dans les provinces maritimes du moins, de la confusion qui existe relativement à la détermination des droits de possession des zones de marées. Des poursuites judiciaires intentées récemment au Nouveau-Brunswick et à l'Île-du-Prince-Édouard révèlent que le besoin de clarifier la terminologie juridique et scientifique employée dans ce domaine et de simplifier la procédure technique qui régit actuellement l'arpentage des zones de marées se fait nettement sentir.

There has been little concern in Canada to date over the precise delimitation of tidal boundaries, but perhaps there should be. The ambulatory nature of these boundaries, comparatively low coastal property values, and minimal litigation have probably contributed to a general lack of interest on the part of the surveying and legal professions. As a visible and practical boundary, the tide mark has served the upland proprietor, the public, and the surveyor well. Why then should surveyors be concerned?

With increasing competition for coastal resources and the concomitant rise in property values, boundary disputes are an unavoidable consequence. Experience in the United States has also shown that as governments play a more active role in the management of these resources, property rights and boundaries can become critical issues. Precise delimitation of the private-sovereign boundary is often required in resolving land use conflicts, implementing legislation, or in cases of expropriation.

Such trends are not restricted to the United States. In a recent issue of the international *Coastal Zone Management Journal* that was devoted to coastal resource use and jurisdictional problems in Canada, *Harrison and Parkes* [1983] predicted that:

> Not only will already developed areas see increased levels of inter-use conflicts, so too will regions which until recently have been virtual wildernesses . . .

Legislation affecting coastal land tenure has already been enacted in the Maritimes with little regard to the impact on boundary delimitation and property rights. Although Canadian litigation involving tidal boundaries is limited, two recent cases on the Atlantic coast have raised boundary issues similar to those that have resulted in costly litigation in the United States.

If the surveying profession is to ensure that tidal boundary delimitation meets changing land tenure requirements, these issues must be addressed. They cannot be resolved appropriately, however, without recognizing the interdependent roles of law, surveying, and science [*Graber* 1980]. This paper therefore examines some of the problems that should be considered by the surveying profession and demonstrates the need for an interdisciplinary approach.

Emerging Issues

Most North American jurisdictions have inherited the vague common-law definition of the private-state boundary, the ordinary high water mark (OHWM). The OHWM has been traditionally interpreted by Canadian surveyors as a physical mark on the shore. While this has been practical and generally sufficient for most coastal land tenure requirements, a number of factors in the United States have led to the development of more precise definitions and survey procedures.

The increasing intensity of coastal resource use near urban centers and recreational areas has been accompanied by escalating land values and concern over the location of shore boundaries. Along the American Atlantic and Gulf coasts, for example, it has been estimated that lands valued conservatively at approximately three billion (1974) dollars would be affected by a difference of only 0.03 metres in establishing the high water datum for boundary demarcation [*National Ocean Survey* 1974]. Where marshlands and other environmentally fragile areas are protected by land use legislation, jurisdictional and property limits have become the focus for conflicting land claims. Subsequent boundary disputes have often resulted from inconsistent surveying and 'scientific' procedures for locating tidal boundaries. Litigation has been costly in terms of surveys, court time, and long periods of uncertainty in land tenure [*Tell* 1982].

The Maritime Provinces have begun to experience similar government involvement in the coastal zone. Environmental concerns have initiated legislation affecting property rights, such as the wide-sweeping and retroactive Nova Scotia *Water Act* [1967]. In the foreseeable future, the Bay of Fundy Power Project could alter water levels, and thus boundaries, throughout the entire Bay of Fundy and Gulf of Maine coastal regions [*Greenberg* 1979]. Governments at all levels are becoming active in developing port improvements, recreational areas, and other major projects. As such developments often involve the expropriation and valuation of coastal lands, the stage is set for boundary litigation. Two Maritime cases illustrate the type of litigation in which tidal boundary surveys may come under scrutiny.

R. Gordon Shaw v. The Queen [1980] concerned an expropriation, in 1937, for the Prince Edward Island National Park. In the original expropriation survey an embayment was delineated on Brackley Bay. When the existence of this feature was later questioned, an ambiguity in the Park description became the center of a boundary dispute. Over the next forty years, three additional surveys were conducted for the federal government to investigate the entitlement issue. One 'survey' relied on vegetation and geomorphological analysis to establish past and present OHWM boundaries.

The plaintiff's claim of $2 000 000.00 for lands valued at $3000.00 in 1938 was rejected by the Canadian Supreme Court as unreasonable, but *Shaw* reflects the increasing value of coastal lands and the potential cost of litigation. While the Court made no rulings concerning the survey evidence, the case demonstrated the current confusion in boundary definition, the problems in applying OHWM survey techniques in marshlands, the difficulties in establishing former tidal boundary locations, and the use of scientific techniques in boundary delimitation.

Irving Refining Limited and the Municipality of the County of Saint John v. Eastern Trust Company [1967] similarly involved an expropriation, in this case, to clear title to a waterlot in Saint John, New Brunswick for the construction of a causeway over Courtenay Bay. For the expropriation plan and description, the tidal boundary was established as the intersection of the mean high water (MHW) datum with the shore. The defendant, who was the upland proprietor, claimed possessory rights to the tidelands and also compensation for the expropriation of riparian rights. The latter issue rested in part on an apparent problem in the survey.

This dispute took over four years to resolve. The Court sought to determine the location of the boundary in the nineteenth century, the nature of subsequent shoreline changes, and the true location of the boundary at the time of the expropriation. Evidence was given by an historian, a soil analyst, port engineers, surveyors, and the then chief tidal officer for Canada, G. Dohler. During the trial, testimony regarding the various tidal datums referred to on numerous plans and charts was described by the Court as being "as clear as the mud in Courtenay Bay".

Tides and Tidal Datums

In both *Shaw* and *Irving* the upland boundary in the expropriation order was defined as the MHW mark. Subsequent interpretations of this term by surveyors and the courts demonstrated a general lack of understanding of the tidal phenomenon on which the boundary definition is based. This confusion was compounded by the absence of a scientific MHW datum definition.

Tides are the periodic rise and fall of the ocean waters in response to the gravitational attractions of the moon and sun on a rotating earth and the centrifugal forces created by the revolution of these bodies around their common centers of gravity. If only a water-covered earth and the effect of the moon with zero declination are considered, two high waters of equal height and two low waters would be experienced each lunar day. Variations in these theoretical semi-diurnal tides are caused by the diurnal, phase, and parallax inequalities and by the effects of land masses.

Since the moon's orbit is inclined with respect to the ecliptic, the tide raising force varies with latitude and lunar declination. Unequal high (and low) waters are produced along most parallels of latitude, an effect known as the diurnal inequality (Figure 1). The observed character of the tide is further influenced by coastal physiography and friction, which modify the theoretical tides through resonance and damping of the constituent tides. Semi-diurnal, diurnal, and mixed tides can thus be found in close proximity, as is the case along the Atlantic coast.

The phase inequality accounts for the fortnightly changes in the resultant of the lunar and solar tide raising forces. When the moon and sun are in alignment, at new and full moon, spring tides with larger ranges than average occur. Near the first and third quarters, the resultant is diminished and neap tides with ranges smaller than average are observed. It is these neap tides that have caused some of the ambiguity in the definition of OHWM.

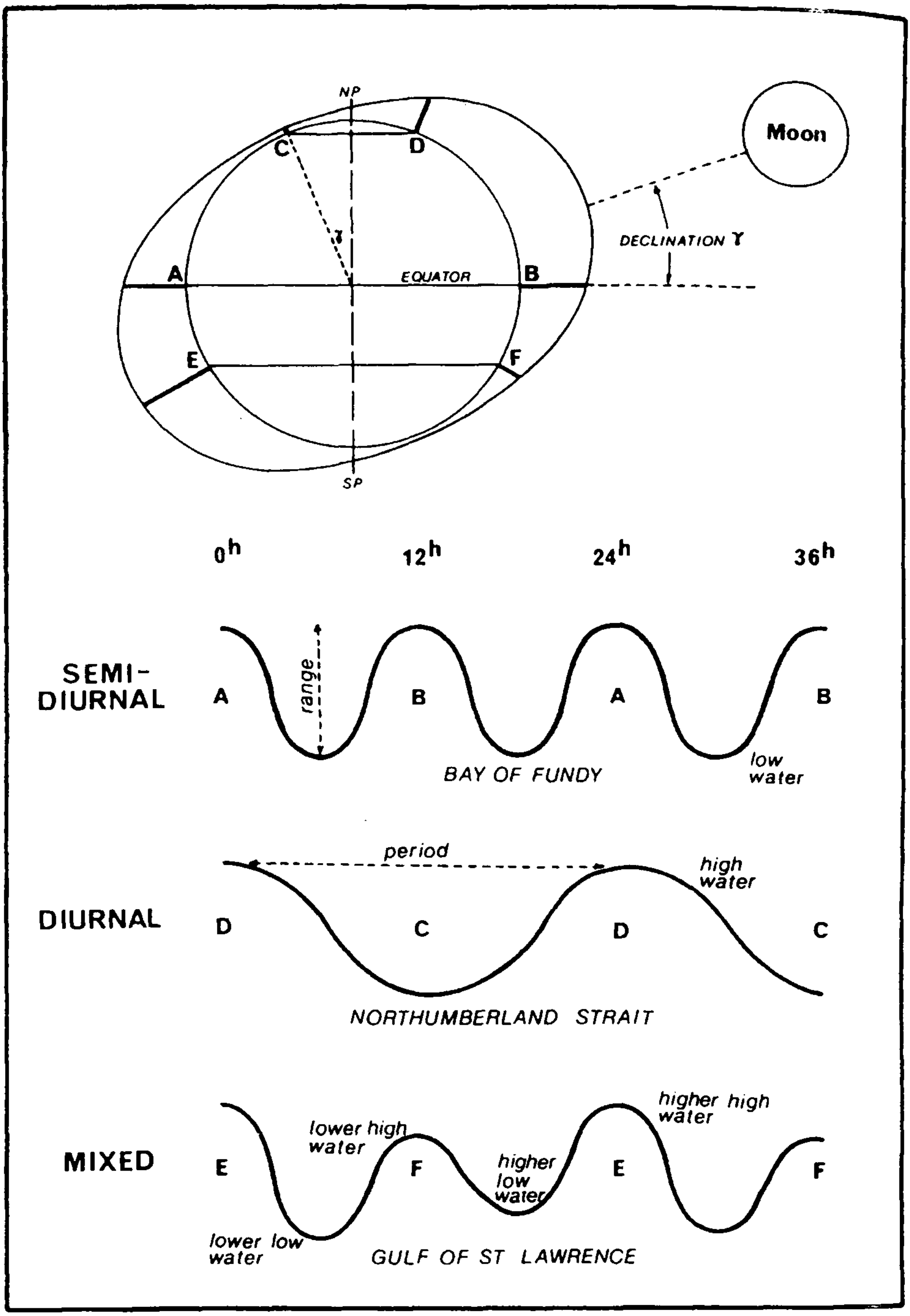
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Figure 1

The elliptical orbits of the moon and earth cause a parallax inequality in the ocean tides. Since the gravitational attractions of the sun and moon are indirectly proportional to the square of their distances, the tide raising forces at perigee and perihelion are increased and unusually large tidal ranges occur. Conversely, near apogee and apehelion tidal ranges are diminished.

Also of particular importance in tidal boundary delimitation is the period of tidal variations combining the relative lunar and solar declinations. Known as the regression of the moon's nodes or nodal tide, the effect has a period of 18.61 years. This period has been recognized in defining tidal datums because it contains all of the significant astronomic tidal variations.

Tidal datums are reference surfaces established as the average water level elevations at a particular stage of tide. For example, the MHW datum of the United States is defined as follows:

> A tidal datum. The average of all the high water heights observed over the National Tidal Datum Epoch. For [tidal] stations with shorter series, simultaneous observational comparisons are made with a control station in order to derive the equivalent of a 19-year datum. [*Balint* 1980]

A datum elevation is fixed at a control station for a particular epoch, the current American Tidal Datum Epoch being defined as the 1960–1978 tidal record series [*Hull et al.* 1981]. The elevation and epoch are periodically updated to represent a new series of observations at permanent stations that monitor long-term trends in datum elevations. This 19-year period contains full cycles of annual variations due to the earth's orbit and nontidal influences, which are generally more significant than longer period tidal variations.

Recently Canadian datum definitions also refer to a 19-year period. In the new *Canadian Tidal Manual*, for example, Higher High Water Mean Tides (HHWMT) is defined as the "average of all the higher high waters from 19 years of predictions" [*Forrester* 1983]. However, datum elevations may actually be computed from a tidal record of one year or less and are defined for navigation and charting rather than for boundary delimitation. Neither the manual nor the *Canadian Tide Tables* [*Fisheries and Oceans* 1983] give a MHW datum definition that takes both daily high waters into account. Whereas HHWMT may approximate MHW in some coastal areas (i.e., relatively small diurnal inequality), coastal modifications of the tides can cause large differences between the datum elevations, even in nearby areas.

An approximate MHW elevation can be calculated from the tide tables by adding all the high waters predicted for that year, but this is a tedious, error-prone procedure. The datum elevation so obtained is based on predicted rather than observed water levels and represents only the astronomic variations and mean sea level for that year. A further limitation of this method is that daily tidal heights are published only for Reference Ports, which have a relatively long tidal record. At Secondary Ports a correction term must be applied for spatial variations.

For locations between Reference or Secondary Ports, local modifications of the tides must be taken into account to obtain an accurate datum elevation. Factors that can affect the time of tide and the observed tidal heights include currents, river discharge, seabed characteristics, meteorological conditions, and coastal configuration. The tidal range in Brackley Bay established for a study in the *Shaw* case, for example, was approximately 50 percent less than that for the nearby Reference Port in Rustico

Harbour [*McCann* 1978]. Barriers, marsh vegetation, and friction on tidal flats can slow the ebb and flow of the tides causing local time variations and a datum slope.

Consequently, tidal datums should not be considered time invariant, level surfaces. Neither a datum elevation nor the time at which a particular water level will occur is necessarily a linear function of distance along the coast. Interpolation and extrapolation of tidal times or heights therefore only yield approximations.

To establish an accurate tidal datum elevation at a survey site, local water level observations must be made. Table I lists the expected accuracies in datum determination for tidal records of varying lengths as given by *Swanson* [1974] and *Weidener* [1979]. If these limits are then compared, for example, with tolerances derived from the *Maritime Accuracy Study* [*McLaughlin et al.* 1977], the magnitude of the problem is evident. Since Secondary Port datum elevations are usually only established from records of one month or less, even tidal information for these stations may not be sufficient for boundary purposes. It should be noted, however, that Table 2 is based on several assumptions: that tidal boundaries require the same accuracy as other boundaries; that horizontal rather than vertical or some other tolerances are appropriate for boundary delimitation; and that boundary surveys require tidal datum establishment.

Tidal Boundary Definitions

The OHWM is by presumption the seaward limit of private ownership along tidal waters in most common-law jurisdictions, although this presumption may be defeated by express words of grant. Some properties in Canada are thus delimited by such boundaries as the ordinary high water spring mark or may extend to the low water mark. Where private rights to the foreshore exist, however, they have generally been granted or leased separate from the upland. With jurisdictional uncertainty and new legislation, the status of these foreshore rights may be in question [*Masland* 1976].

The foreshore in feudal England was customarily considered to be part of the upland manor. In the sixteenth and seventeenth centuries, these lands were claimed by Queen Elizabeth I and her successors, with the intention of regranting this strip of valuable coast as a new source of revenue. However, the attempts to assert sovereign ownership met with public opposition and were generally defeated by the courts [*Farnham* 1904]. Expanding national interests in commerce and navigation were largely responsible for the eventual acceptance of the *jus publicum* concept, that is, lands held in trust by the Crown for the public [*Anon.* 1970]. Sir Matthew Hale, in his treatise *De Jure Maris* [c. 1666–1667], defended the Crown's *primae facie* right to lands covered by the 'ordinary' tides and the term OHWM thus entered the common

TABLE 1: Estimated Accuracies of Datum Elevations for Comparison of Simultaneous Observations

Period of Observations	Estimated Accuracy (metres)
1 day	0.076
1 month	0.040
1 year	0.015
9 years	0.005

TABLE 2: Derived Vertical Tolerances in Datum Elevations for Representative Beach Slopes

Zones	Horizontal Tolerance (metres)	Vertical Tolerance (metres) 5% slope	10% slope	25% slope
Urban	0.050	0.003	0.005	0.013
Suburban	0.100	0.005	0.010	0.025
Rural	0.500	0.025	0.050	0.125

law. By the time major settlement occurred in eastern Canada, the OHWM was well established as the private-state boundary.

It is the interpretation of the OHWM that has caused both legal and surveying problems. The difficulty originates in Hale's distinction between three types of tides: high spring tides "that happen at the two equinoxes"; "spring tides which happen twice every month, at full and change of moon"; and "ordinary or neap tides, which happen between the full and change of moon" [*Hale* 1666–67]. As *Shalowitz* [1962] points out, neap tides cannot be equated with average, mean, or 'ordinary' tides in scientific terminology and the classification is ambiguous. While in some jurisdictions ordinary tides have been interpreted as neap tides [as for example in California, *Teschemacher v. Thompson* 1861], Canadian law has excluded extraordinary tides from the definition of OHWM [*Lee v. Arthur* 1918; *Doig* 1978].

The leading precedent for Canadian interpretations of the OHWM was set in the British case, *Attorney-General v. Chambers* [1854]. In *Chambers*, ordinary tide was defined as "the medium tide between spring and neaps". The Court also drew attention to Hale's reasoning that the upland should be restricted to those lands that are "for the most part dry and manoriable", that is, capable of cultivation.

The traditional 'limit of vegetation', often stressed in surveying, may be partially based on this distinction, although survey definitions of the OHWM encompass other marks left by the tides. In the regulations pursuant to the *Nova Scotia Land Surveyors Act* [1977], the OHWM is defined as:

> the limit or edge of a body of water where the land has been covered by water so long as to wrest it from vegetation, or as to mark a distinct character upon the vegetation where it extends into the water or upon the soil itself. [*N.S. Reg. 42/79* 1979]

Similar definitions can be found in Canadian and American survey regulations and some of the merits and limitations of this interpretation have been debated by *Doig* [1979; 1980] and *MacDonald* [1979].

It was precisely a dispute over the interpretation of ordinary tides as neap tides and the OHWM as a vegetation line that led to the landmark U.S. federal decision, *Borax Consolidated, Ltd. v. Los Angeles* [1935]. In this case, Borax was granted shore property in Los Angeles Harbor through a federal patent. When the city sought to quiet title to adjacent tidelands, Borax claimed that the boundary was delimited by a meander line shown on the patent or, alternatively, by the line of mean neap tides or the line of vegetation. All three lines extended well below the MHW mark claimed by the city [*Corker* 1966].

The U.S. Supreme Court decided that the OHWM "meant the intersection of a tidal datum with the shore, and had no particular relation to a physical tide mark or vegetation line" [*Maloney and Ausness* 1974]. Recognizing the U.S. Coast and Geodetic Survey definition of the MHW datum, the Court held that "an average of 18.6 years of tidal observations should be used to determine the datum elevation" [*Borax* 1935].

As yet, there is no equivalent legal recognition of the MHW line (MHWL) in the Maritimes, although the Court in the *Irving* case accepted the establishment of a MHWL by two methods. Some provincial statutes, such as the N.S. *Beaches Preservation and Protection Act* [1975], also refer to the MHW mark, but no definition of a tidal datum is given. At the federal level, the limit of provincial jurisdiction in British

Columbia was defined as the OLWM [*Re: Offshore Mineral Rights in British Columbia*, 1967], although the expropriation order for the National Park in the *Shaw* case referred to the MHW mark.

In *Shaw*, the Court referred to several legal authorities for an interpretation of the OHWM, which did little to eliminate the ambiguity. Using the terms ordinary, average, medium, and mean interchangeably, the Court first cited a British legal scholar who defines the ordinary high tide as:

> taken at the point of the line of medium tide between the spring and neaps, ascertained by the average of the medium tides during the year . . . [*Wisdom* 1979]

Reference was then made to La Forest, an authority on water law in Atlantic Canada. He lists all of the common terminology, stating that by OHWM

> is meant the medium high water mark at ordinary or neap tides . . . It is this medium tide that has been adopted as the ordinary or mean high water mark. [*La Forest et al.* 1973]

La Forest attempts to "add precision" by noting further that "the law takes cognizance of three types of tides" but then defines those tides distinguished by Hale. Whether La Forest has clarified matters is doubtful, but perhaps he is also pointing out a distinction between the legal and scientific definitions of neap tides and MHW.

OHWM Surveys

A physical mark is a convenient interpretation for surveyors which may also serve as the practical limit of upland occupation. The relationship, however, between vegetation or other features and the reach of the average or medium high tides can sometimes be obscure. Two coastal areas pose particular problems in surveying the OHWM as a vegetation line:

1) marshlands extending below MHW, as in *Shaw* and *Borax*;
2) open coasts or tidal flats, as in *Irving*, where vegetation has been stripped above the limit of average high tides by waves, winds, and storm tides [e.g., *Doig* 1979] or, in some cases, by coastal development.

Where the limit of vegetation is not a good indication of the ordinary tides, surveyors have recourse to a number of other tide marks. Seaweed lines indicate the reach of the last tide, but there are often several such lines on the shore representing storm tides, spring tides, or the previous higher high water. Similarly, lines of driftwood and debris generally only mark storm tides. Rock discoloration and ridges or berms caused by the wash of waves have also been identified as the OHWM. In all cases, this evidence approximates the limit of the average tides and reflects the imprecision of the term 'ordinary'. The accuracy and consistency of surveys will depend on the experience of the surveyor and his knowledge of local tidal conditions [*Nichols* 1983].

Wherever vegetation extends below the average high water, the OHWM may be interpreted as the 'change in vegetation' or a 'distinct character' on the shore. The delineation of the change in vegetation has been the subject of debate and litigation in the United States, particularly where states have claimed large expanses of tidal marshes based on this criterion. Biological evidence was also presented in the *Shaw* case. A distinction can be made between two approaches.

1) In ground surveys the observed limit of salt water vegetation is delineated by conventional methods. This implies that the surveyor has an adequate knowledge of

local vegetation types and tidal conditions; and

2) Remote sensing techniques based on the interpretation of plant species signatures have been applied in coastal and wetland mapping. Although more efficient than ground surveys, the accuracy of the analysis may be impeded by the scale of the imagery and the existence of transition zones from saltwater to upland vegetation which are difficult to classify [*Porro and Weidener* 1978].

In *Shaw* three surveyors delineated a small ridge on the seaward edge of a tidal marsh as the OHWM. At the time of the original expropriation survey, winter ice may have obscured coastal features. In any case, the surveyor deviated from this ridge, delineating an 'embayment' which did not appear in subsequent surveys. Biological and geomorphological evidence showed the embayment consisting of sand dunes, high and low marsh, and a transition zone. The criterion applied in identifying the appropriate change in vegetation character (biological OHWM) was the frequency of tidal innundation. This analysis showed that some areas landward of the ridge (surveyed OHWM) were covered by ordinary or average tides and other areas in the embayment were actually part of the upland at the time of the expropriation [*McCann* 1978].

Although there was no ruling in *Shaw* concerning the weight to be assigned the biological evidence, a recent landmark decision in New Jersey favored conventional survey methods over vegetation analysis by remote sensing. The surveys included the establishment of a MHWL, augmented by tide-controlled aerial photography and verified by physical evidence of the boundary. In making its decision, the Court commended the multidisciplinary approach in field surveys and the consistency of the results [*Porro and Weidener* 1980]. Since marshlands have relatively flat terrain and complex vegetation, boundary establishment by either datum recovery (MHWL) or physical features (OHWM) alone may lead to large discrepancies that could be challenged in courts.

MHWL Surveys

With the adoption of the *Borax* MHWL definition in many American coastal states, new survey methods were required. Three procedures currently in use are: the delineation of a contour; the delineation of the visible waterline at the appropriate stage of tide; and either of these methods controlled by local tidal observations. The first two methods have been applied to a limited extent in the Maritimes, in some cases to verify the OHWM [*Nichols* 1983]. However, without a MHW datum definition and tidal observations to establish a local MHW datum, these procedures may not provide any improvement over traditional survey methods.

While the contour method would appear to be appropriate for a MHWL survey, it is based on the assumptions that a MHW elevation is known or can be derived for the survey site and that the MHW datum is a fixed, level plane. Inaccuracies in boundary location can occur from a number of sources, including:

1) direct interpolation and extrapolation of datum heights from remote stations (These approximations disregard nonlinear variations in datum elevation between the control station and survey site. As tidal station density is relatively low in Canada, these errors could be significant);
2) changes in MHW elevation along the property boundary due to local influences;
3) the lack of correspondence between the datum intersection and wave action that may carry water further shoreward;

4) the fact that MHW elevations derived for Secondary Ports may not meet accuracy requirements for establishing a MHWL boundary; and
5) errors in transferring elevations and in obtaining geodetic elevations related to chart datum, to which tide table predictions refer.

In *Irving* the Court suggested that the most obvious method of delineating the MHW mark would have been by running a contour at the MHW elevation but then accepted the waterline survey conducted for the expropriation. On a day and a time when the MHW elevation, as calculated from the tide tables, was predicted to occur at the permanent tide gauge in Saint John Harbour, the observed waterline was staked at the survey site. Although a waterline survey should ensure that a local tidal datum elevation is established, the method has two major sources of error.

1) It is time dependent and any error in calculating the time of high water at the survey site (which may differ from that predicted at the control station) can cause horizontal displacement in the boundary staked. These errors will be more significant in areas with large tidal ranges and/or gentle slopes, or when a long shoreline is staked over an extended time interval. Local influences, such as friction, embayments, or obstructions, may limit the use of interpolation and extrapolation procedures for deriving an accurate local time of MHW; and
2) Tide table predictions are presently the only source of datum elevations and observed water levels can differ markedly from predicted levels on any given day, largely due to meteorological conditions or such local influences as river discharge.

The 0.15 metre vertical discrepancy in datum establishment discussed in *Irving*, which the Court attributed to a leveling error, illustrates the significance of these errors. In question was the ownership of a corresponding 3.8-metre strip of tideland. Little attention was given in the case to possible timing errors in staking the waterline in Courtenay Bay at the predicted time of MHW for the Reference Port (Saint John Harbour); but visual inspection of the furthest reach of the tides may have compensated for any difference. More importantly, the Court assumed that the elevation of MHW predicted for the Reference Port would be the same as that observed in Courtenay Bay, even though the tide gauge in the harbour is located near the mouth of the Saint John River. Part of the survey discrepancy may therefore have been due to local variations in tidal datum heights or times. The fact that the observed high water level at the Reference Port on the day of the survey was 0.06 metres higher than predicted may also have been a contributing factor. Similar difficulties in using tidal predictions for boundary surveys were noted as early as 1918 in *Nelson v. Pacific Great Eastern Railway Co.*

Whereas waterline surveys based on remote sensing techniques can provide efficiency for coastal mapping, the suitability of this technique for boundary surveys will depend on the accuracy achieved. The accuracy will in turn depend on the scale of the photography and the degree to which exposure time is correlated to the local time of MHW. According to the *Regulations* [1979] made under the *Nova Scotia Land Surveyors Act* [1977], "controlled" aerial photography may be used in delineating natural boundaries, but whether this necessarily infers tide control in addition to geodetic control is not clear.

Recognizing the problems inherent in MHWL surveys, American surveyors have improved tidal boundary delimitation by controlling contour and waterline surveys with tidal observations made at the survey site. Once a MHW elevation is established for the site, a contour can be run for a short distance or a waterline may be delineated at a time when this MHW level is observed on one or more tide staffs erected along the boundary [e.g., *Weidener* 1979]. The major difficulty is the establishment of an accurate local MHW elevation. One month of observations, let alone 19 years, would make MHWL surveys impractical for boundary delimitation.

To solve this problem, methods have been developed for establishing MHW datum elevations from comparison of short tidal records. Water level observations made at the survey site over one or more days are related to observations made simultaneously at a control station with a known MHW elevation. Procedures have also been developed for areas where only partial tidal cycles can be observed, such as in marshlands or on tidal flats [e.g., *Cole* 1979; *Weidener* 1982]. A new method that accommodates tidal predictions, proposed by *Maddox* [1982], may be more suitable for Canadian tidal information. The accuracy in datum establishment using these methods will depend on a number of factors, including:

1) the similarity in tidal characteristics, such as range and type of tide, at both sites (for example, the control and survey station should be on the same body of water);
2) the accuracy of the known MHW elevation at the control station (This introduces a particular problem in Canada where tidal station density is low and Secondary Port predictions are based on approximately one month or less of tidal observations); and
3) the recoverability of the MHW datum elevation at the control station, that is, the availability of accurate tidal benchmark information.

These short-term methods presuppose a MHW datum definition, a relatively dense network of tidal stations with updated ties to geodetic benchmarks, and accessibility to accurate, updated, and appropriate tidal information.

Responding to the need for legal and scientific support for improved MHWL surveys, some American states have implemented coastal boundary programs. The objectives include densification of tidal stations, legislation regarding boundary definition and survey procedures, and establishment of information networks that distribute scientific and surveying information required for boundary delimitation and other purposes [e.g. *Florida Coastal Mapping Act* 1974]. Federal/state cost sharing help to offset the high initial costs of implementing these comprehensive programs.

The Ambulatory Boundary

One major objection lawyers and surveyors may have to requiring precise delimitation for all tidal boundaries is the ambulatory nature of either the OHWM and MHWL. Through the riparian right of accretion, the location of the tidal boundary shifts over time with changes in mean sea level and coastal configuration. A water mark or line is a natural boundary governing all survey measurements and gradual changes in location do not affect the status of the boundary [*Saueracher et al. v. Snow et al.* 1974]. Since measurements are only an indication of the location of the boundary at the time of the survey [*Irving* 1967], the OHWM or MHWL delineated on a plan should be referenced to the day the survey was performed.

Two major problems are associated with ambulatory boundaries. The first is determining whether the shoreline change is based upon accretion/erosion or avulsion. Theoretically in the latter case, the boundary location is not altered. In practice, most sudden and perceptible changes are masked by subsequent coastal processes. While this issue is primarily one of law, science and surveying assist in determining the *de facto* nature and extent of such changes. Similarly, the problem of relocating boundaries fixed as former water marks or lines may involve multidisciplinary expertise.

In *Irving*, artificial changes in the shore of Courtenay Bay were created by the dumping of waste material over an embankment by successive upland proprietors and through the construction of breakwaters. The Court held that these actions were, for the most part, consistent with the riparian owner's right to protect his property from the action of storms. This was a practical solution in a situation where the former water line locations were virtually impossible to reestablish with any certainty. Evidence presented to establish the nature and extent of shoreline changes included the history of shipbuilding in the area, soil analysis, and numerous ancient charts, maps, and plans. Greater weight was assigned to those documents prepared specifically for accurate property or shoreline location.

Evidence of coastal changes in *Shaw* included ancient charts and plans showing the landward migration of a barrier island which eventually formed the lands in question. One chart prepared by Captain Holland in 1775 was recognized as an accurate portrayal of conditions at that time based on his reputation for reliable surveys. Scientific evidence presented to establish the nature of the accretion and the location of the OHWM at the time of the 1937 survey included an analysis of vegetation types from aerial photographs taken near the time of the expropriation and subsurface soil analysis.

The difficulty in relocating former tidal boundaries has been documented in several American jurisdictions where states have claimed lands formerly covered by tidal waters. In New Jersey, state claims through legislation to marshlands, filled in over centuries by upland owners, have recently been limited to forty years through a public referendum [*Graber* 1983]. Not only have such claims caused insecurity of tenure over many years, but difficulties were also encountered in weighing diverse and sometimes contradictory evidence to support private and public interests [*Porro and Telekey* 1972].

Similar legislation affecting riparian rights and boundary delimitation should be avoided at all costs in Canada, although boundaries have already been fixed in areas of intense coastal use. For example, the National Harbours Board has at least five definitions for various portions of its landward boundaries in Saint John Harbour. In addition to fixed survey lines, these include the 'line of occupation, 1936' and 'Low Water Ordinary Spring Tides, 1936' [*Vye* 1983].

Need for an Interdisciplinary Approach

As the problem of locating former water lines demonstrates, the delimitation of tidal boundaries comprises many areas of expertise. We believe that the key figure is the surveyor. While he relies on the principles and definitions of law and on information and techniques provided by science, he is the expert in boundary delimitation.

It will be to the surveyor's advantage not only to have the legal definition of the high water boundary clarified, but also to ensure that this definition is based on a scientific understanding of the tidal phenomenon and denotes appropriate survey procedures. By confusing ordinary with neap tides, the law ignores scientific terminology and the OHWM remains subject to diverse interpretations. The terms 'mean' and 'medium' have been recognized in Canadian law, but no attempt has been made to define a MHW datum for survey purposes that could be calculated precisely and unambiguously.

To avoid further confusion, a distinction should be made in law and surveying between the OHWM and MHWL. The former refers to a physical mark that approximately delimits the extent of the tides taken as ordinary, 'whatever be the right interpretation of that word' [*Chambers* 1854]. The latter implies the establishment of the intersection of a precisely defined tidal datum with the shore. Without such legal guidelines, surveys may continue to be inconsistent and thus potentially subject to dispute in litigation.

The OHWM calls for well established survey methods and makes few requirements of other disciplines. However, the consistency and degree to which the boundary delineated represents the limit of the 'average' tides will depend on local conditions and the experience of the individual surveyor. As expressed in one British Columbia case:

> It would appear that the surveyor, at the time when he is fixing the high-water mark, under such practices, becomes a judge as to where it exists. He is uncontrolled by authority. This practice [delineation of driftwood lines], however, seems to be generally accepted and followed. [*Nelson v. Pacific Great Eastern Railway Company* 1918]

Perhaps MHWL surveys can provide the precision that survey standards require for other boundaries, but the additional costs will undoubtably be significant. There is also greater reliance on accurate tidal information. Without the support of a datum definition and standardized procedures that stress local tidal datum establishment, MHWL surveys may result in larger horizontal discrepancies than methods based on physical features. (Field tests of OHWM and MHWL procedures in New Brunswick, planned for 1984, will hopefully provide an assessment of these discrepancies.)

To support MHWL survey procedures, or to verify an OHWM boundary, the surveyor should be concerned with improving tidal information. Attention should be given to the determination of expected accuracies of datum elevations at tidal stations, possible densification of the Canadian tidal station network, and the publication of MHW elevations and in a format suitable for cadastral surveying. Tide table predictions may not be appropriate for accurate boundary surveys. Further study of the factors affecting local sea levels in Canada would also assist in evaluating MHWL survey procedures and accuracies.

The surveyor must also accept scientific evidence, such as geomorphological or biological analysis, with caution in boundary delimitation. Although this type of evidence may assist in locating former tidal boundaries and remote sensing may be an efficient tool for coastal mapping, the weight afforded these procedures by the courts is as yet unclear.

Like the tidal boundary itself, the delimitation issues can be elusive. There has been a tendency to reduce the problems to a question of tide mark or tidal datum. Perhaps the question that should be addressed is how tidal boundary delimitation may best meet the changing land tenure requirements of the coastal zone. From their experience in the courtroom and the field, *Porro and Weidener* [1978] have made the following comments:

> The world of the lawyer, surveyor, and science have much to lend each other. The aim should be reasonably technically and scientifically based standards for establishing

> a tidal boundary, with the necessary legal stability that is required by the courts . . . In the process of establishing this [tidal] boundary, the world of science, and its current experimentation, can greatly contribute. On the other hand, the world of jurisprudence must strive to establish legal guidelines which are technically rooted. Only with such a combination can the necessary legal stability that is required for title ownership, be achieved.

If problems continue to be addressed by each discipline independently, without considering the implications to others, then survey standards, legal definitions, and tidal information will remain inadequate whenever precise delimitation is required.

We therefore recommend that the Canadian Institute of Surveying (perhaps in conjunction with the Canadian Council of Land Surveyors and other interested bodies) establish a working group to identify and assess the relevent issues with the objective of drafting model standards and procedures for tidal boundary delimitation. Although the group should include land surveyors and hydrographers, it should also draw on the expertise of other disciplines. Thus, the committee should strive to involve members of the legal profession, oceanographers, environmentalists, biologists, and geographers in discussion and workshops to promote an understanding of the current problems, their implications, and potential solutions. It is proposed that this working group initially meet at the 1985 annual meeting of the Canadian Institute of Surveying.

With its broad range of expertise and its roots in both science and law, the surveying profession is in a unique position to initiate cooperative efforts to reach appropriate solutions. To date there has been little evidence of such coordination in tidal boundary delimitation. The result, in many respects, has been added confusion rather than the clarification of definitions and survey procedures. We therefore believe there is a need to view tidal boundary delimitation from a new perspective: an interdisciplinary approach.

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